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ABSTRACT

The concepts of imagery, mathemagenic behaviors, and generative imagery are reviewed; and the learner's use of visual imagery is discussed. Several studies have supported the idea that imagery is an active mental process that gives birth to learning. The concept of mathemagenic control or manipulation is of interest to the instructional designer. There are two mathemagenic behavior control techniques: directive and inductive control. Directive control refers to the selection of a processing technique that facilitates processing, although the type of processing is left to the learner's judgment. Arguments over which type of control is better continue, as recent research demonstrates. Generative learning implies that the learner is active in the generation of relationships, actively involved in instruction, attentive to informational structures, and aware of the mediational processes used. Some researchers regard generative learning as a subset of mathemagenic processing. Studies examining the relationship between mathemagenic behavior and instructionally induced imagery are explored. The role of visual imagery as a mediational force during the mathemagenic/instructor provided or the mathemagenic/generative strategy must be further examined. (Contains 50 references.) (SLD)

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Learner Generated Versus Instructor Induced Visual Imagery

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Imagery

Imagery Types

The study of mental imagery is not limited to visual imagery, or the visual manifestations appearing in our minds. Millar (1990) clarifies the notion of mental imagery by stating that visual imagery is only one facet of mental imagery. Other forms of imagery are tactile imagery (imagining what objects feel like) and olfactory imagery (imagining what things smell like). Imagery types are only limited to the range of senses a person possesses. Images are direct representations of the things which they reflect. Millar (1990) states that images, "unlike arbitrary associations between words and things, 'resemble' the objects they depict" (pp. 129).

Associative Learning

Paivio (1979) discusses a theory of imagery called associative learning. He describes associative learning as playing a mediational role in various memory strategies. The associative view holds that mental images can be evoked by stimuli with which the imaged objects or events have been associated in the past, and that these visual images could themselves combine associatively.

A more specific discussion of associative learning is the concept of paired-associate learning. Pressley (1977b) describes paired-associate learning as a task situation where a list of pairs (usually pairs of words, pictures, pictures and words, or actual objects) is presented to a learner. Each pair consists of a stimulus item and a response item. The objective is to learn the correct response to each stimulus.

This theory revolves around the use of concrete and abstract concepts. A concrete concept possesses a high degree of physical qualities such as size and texture which can be consistently observed across a wide spectrum of individuals. An example would be an apple which could be consistently described as being rounded, smooth, red, and hard.

An abstract concept possesses fewer physical characteristics and is often harder to consistently define. An example would be love, which has many meanings, no discernable size or shape.

The more concrete characteristics a concept has the greater the concrete value of that concept. Paivio (1979) theorizes that the more concrete value there is to a concept, the more imaginal that concept is. With this in mind there exists a continuum of imaginability. This continuum is illustrated in Figure 1.

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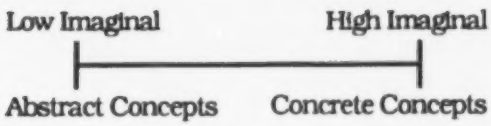

Figure 1. Continuum for imaginability of concrete and abstract concepts.

Paivio's (1979) concept of imaginability, tied to concreteness, agrees with Reese's (1970) research which indicates that it is easier to form visual imagery of concrete words than it is for abstract words. Thus words which possess concrete value would be more memorable than words which possess virtually no concrete value.

To illustrate the theory of paired-associate learning, consider that the word "form" may have several meanings and can be quite abstract. To remember the word "form" a learner may develop an association between the word and a more concrete concept such as "a car." If the learner successfully develops an association between the word "form" and the concept of "a car" then the theory of associative learning states that the learner can recall the abstract concept along with the more easily remembered concrete concept (Paivio, 1969).

Paired-associate learning is the foundation of the conceptual peg hypothesis (Paivio, 1971) which Gambrell and Bales (1986) maintain is central to associative learning. This hypothesis assumes that "key images" serve as mental "pegs" to which associated information is hooked for storage and retrieval (Gambrell & Bales, 1986, p. 455). These pegs can occur naturally or can be strategically rehearsed to improve the chance of less salient information being retrieved (Sadoski & Quast, 1990).

Note that in the previous illustration the word "form" was hooked onto the image or mental peg of "a car." When such a pair is successfully associated or hooked together the learner can use the concrete image of "a car" to retrieve the abstract word "form". Taking the example further, if the learner is attempting to develop an understanding of the word "form" as it relates to artistic style then the learner can associate the word "form" with a particular "car", such as the Corvette which our hypothetical learner owns. When asked what is meant by "form" on a test the learner could recall the Corvette and remember that it's unique body style is an example of "form" as it is defined in this learning situation.

Age, Experience, and Memory Capacity

Another facet of imagery is one's ability to image and its apparent relationship to age. Research has shown that the greatest changes in visual imagery construction occur between the ages of five and eight (Youniss & Robertson, 1970). For this reason the ability to image has been assumed to be related to the age of the learner.

Pressley (1977b) disagrees, however that age directly influences a learner's ability to image. According to him the ability to generate internal visual elaborations is a developmental phenomenon and thus more closely related to age *and* experience. Pressley is not alone in his conclusion (Miccinati, 1982). In more recent work Pressley, Cariglia-Bull, Deane, & Schneider (1987) examined the hypothesis that a learner's ability to image goes beyond age and experience.

A number of studies, designed to look at memory capacity, support the use of imagery while reading for the improvement of recall for high school (e.g., Anderson & Kulhavy, 1972) and college-age students (e.g., Denis, 1982; Seingart & Glock, 1979). Cariglia-Bull and Pressley (1990) investigated the theory that individual differences in short-term memory capacity may affect children's success in carrying

out imagery instructions. Indeed, short-term memory capacity may be a more critical factor in text learning than learning by listening (Cariglia-Bull & Pressley, 1990; Pressley et al., 1987).

Cariglia-Bull and Pressley (1990) found that short-term memory capacity relates to imagery and performance. They found that the greater the short-term memory capacity the greater use subjects could make of imagery instructions.

Pressley et al. (1987) found that those subjects with higher short-term memory scores were more successful at utilizing an imagery strategy than subjects with lower short-term memory scores. The conclusion from these results indicate that when learners are given mental control process instructions they rely on processes which do not put great pressure on short-term memory (Pressley et al., 1987).

Pressley et al. (1987) are then stating that imagery capability is not so much a product of age as it is a product of short-term memory capacity. If however, short-term capacity develops experientially then age, indirectly remains an indicator of imagery capability.

In any case, by the age of 6 or 7 years, children are capable of producing internal elaborations of paired associates. By the age of 8 years children can successfully apply the strategy of self-generated imagery to complex tasks such as prose learning (Lesgold, McCormick, & Goinkoff, 1975; Pressley, 1976).

Gambrell and Bales (1986) contend that the notion of imagery as unchanging mental images has given way to a new outlook. They state that the current conception of imagery is that of an active information-handling process. That imagery is an active mental process leads to the next concern of this examination: mathemagenic behavior.

Mathemagenic Behaviors

Rothkopf (1970) defines mathemagenic behaviors as those behaviors which "give birth to learning" (p. 325). He coined the term mathemagenic from the Greek root mathemain (that which is learned) and gignesthai (to be born).

The concept of mathemagenic behavior implies that the learner's actions play a key role in the learning process (Rothkopf, 1970). When the learner is exposed to some stimulus (i.e., prose) the information does not simply enter the learner's brain and stay there. There are mediating processes, under the learner's control, which either facilitate or interfere with learning the information. According to Rothkopf (1970) the chief purpose of the study of mathemagenic behaviors is to understand how the learner's cognitive processes affect the attainment of instructional objectives.

Mathemagenic Effects

Rothkopf (1970) describes mathemagenic behaviors as having two effects: (1) mathemagenic positive and (2) mathemagenic negative. Two other effects (mathemagenic neutral and mathemagenic unknown) are not directly relevant to instructional design and so will not be addressed here (Rothkopf, 1970).

Grabowski (in progress) identifies the first two effects as of primary importance to instructional design for their ability to describe a stimuli's effect on mental activity. A mathemagenic positive effect means that the stimuli was conducive to learning specified objectives. A mathemagenic negative effect refers to a stimuli's interference with the learning of a specified objective. Rothkopf (1970, p. 327) specifically describes mathemagenic behaviors as: "Those student activities that are relevant to the achievement of specified instructional objectives in specified situations or places."

Classification of Mathemagenic Behaviors

Rothkopf (1970, p. 328) describes three classifications of mathemagenic activities. They are as follows:

Class I. *Orientation*: Getting Ss into the vicinity of instructional objects and keeping them there for suitable time periods. In certain institutional settings, this also involves control over activities that may distract or disturb other students.

Class II. *Object Acquisition*: Selecting and procuring appropriate instructional objects. Main-tenance of selection and procurement activities.

Class III. *Translation and Processing*: Scanning and systematic eye fixations on the instructional object; translation into internal speech or internal representations; the mental accompanyments of reading: discrimination, segmentation, processing, etc.

The first two classifications of mathemagenic activities are directly observable and to some degree directly measurable. The third classification contains some directly observable activities through the observation of biological functions, but also contains activities of a covert nature. These activities which take the form of cognitive processing can be inferred only through indirect observation (Rothkopf, 1970).

As stated before, activities within classifications I and II are mathemagenic so long as they can be directly inferred to be relevant to "the attainment of the performance specified by an instructional objective" (Rothkopf, 1970, p. 329).

It is imperative that class I and II mathemagenic classifications occur in order for class III mathemagenic activities to be inferred. This must be remembered as the remaining discussion of mathemagenic activities will focus on those inferred activities in class III.

Class III mathemagenic activities involve three actions which are discriminated by stimulus control and observable muscular action (Rothkopf, 1970). The three actions are translation, segmenting, and processing. These activities exist on a continuum as shown in figure 2.

Class Three
Mathemagenic Activities

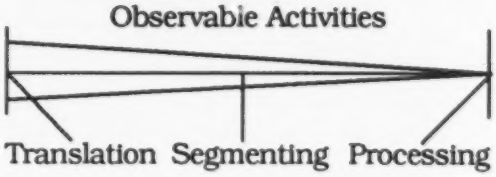

Figure 2. The continuum of mathemagenic activities for observable activities and direct stimulus control.

What this continuum illustrates is that an aspect of the first category of mathemagenic activities, translation, can be directly observed by monitoring eye muscle movements. In order for translation to occur the eye must first scan the text. These observations confirmonly that the learner's eye has scanned the page.

Structure of the text will dictate how the eye scans the page and so, to some degree, translation is also under under direct stimulus control. This means that the instructional materials control much of this activity. The direct opposite can be said of processing which is more independent of direct stimulus control and is quite covert. Rothkopf (1970) refers to processing as being on a "deeper" level than translation or segmenting (p. 329).

The translation stage involves a physical scan of the instructional materials and the creation of a mental representation of the instructional materials. Segmentation involves the linkage of information units during the scanning of instructional materials. Processing is the deepest stage. Rothkopf (1970) believes that it is at this stage that information is interpreted and review processes are initiated.

Inductive and Directive Control

The concept of mathemagenic control or manipulation is of interest to the instructional designer. Rothkopf (1976) refers to two mathemagenic behavior control techniques: directive and inductive control. Directive control refers to the selection of a processing technique which is induced by the instructional materials.

The instructional designer structures the lesson to induce the learner to utilize a specific processing technique. For instance, the instructions for a particular unit may read "Tropical rain forests are lush, green forests which are located primarily near the equator. Picture in your head a tropical rain forest." This instruction is attempting to induce the learner to utilize visual imagery as a processing technique. As shown in the above continuum such control is not necessarily an easy task. Inductive control refers to instructional activities which facilitate processing, though the type of processing is left to the learner's judgment.

Arguments over which type of control better facilitates learning continue (Grabowski, in progress; Jonassen, 1988). Incorporating control of mathemagenic behaviors into instructional materials is the concept of Frase's (1969) cybernetic control. Barry (1974) asserts that mathemagenic behavior is a learning variable which can be manipulated by the experimenter or instructional designer. He believes that control of these behaviors is better incorporated into the instructional materials than vesting it with the learner. Thornton, Bohlmeyer, Dickson, and Kulhavy (1990), however, state that imposed processing strategies may interfere with processing strategies which the learner is already familiar with and prefers. While the manipulation of mathemagenic processes is possible, not all mathemagenic activities can be controlled (Rothkopf, 1970).

Kardash and Amlund (1991) conducted an investigation of those overt and covert information-processing activities used by learners. A subsequent investigation revealed that no consistent relationship existed between any covert and overt strategies (i.e., the use of a particular overt strategy does not guarantee the use of a particular covert strategy).

Grabowski (in progress) explains that the important outcome is to facilitate active mental processing in learning. It is a well accepted concept that learners who are actively involved in the learning process learn more than those who take a passive role (Sutliff, 1986).

Generative Learning

Wittrock's generative learning model (Wittrock, 1974a, 1978, 1981, 1990; Wittrock and Carter, 1975) is a process oriented cognitive processing model that assumes that the reader actively generates two types of rela-

tions: "(1) between the text and the learner's knowledge and memories of experience, and (2) among the units of the text, such as the words, sentences and paragraphs" (Peled & Wittrock, 1990, p. 175). Carnine and Kinder (1985) observe a seemingly synonymous relationship between generative strategies and schema theory (e.g., Mandler & Johnson, 1979; Thorndyke, 1977). They state that schema theory "attempts to explain the organization and integration of new information with previously existing information" (Carnine & Kinder, 1985, p. 21).

Teachers can utilize the generative model by encouraging their learners to attend to the text, relate it to their own knowledge and experience and then build associations, abstractions, and inferences from it (Linden & Wittrock, 1981). The generation of associations and relations can be facilitated through the use of verbal representations (Linden & Wittrock, 1981). Learners can generate verbal representations through the use of "text-relevant summary sentences, headings, inferences, main ideas, critical comments, and evaluations" (p. 45). Imagninal representations, such as pictures, images, graphs, illustrations, diagrams, and drawings can also be used to generate associations and relations.

In the generative model of learning "teaching that induces learners to perform generations relating the parts of the text to one another, or to the readers' background and experience, enhances comprehension" (Linden & Wittrock, 1981, p. 54). Wittrock's research (Doctorow, Wittrock & Marks, 1978; Linden & Wittrock, 1981; Peled & Wittrock, 1990; Wittrock & Carter, 1975) demonstrates two learner behaviors in the generative learning model. They are:

> Learners construct meaning of the text by using their information processing strategies, aptitudes, and stores of specific memories to generate interpretations of the written material (Peled & Wittrock, 1990, p. 175).

and

> Learners use their strategies, aptitudes and memories to generate meanings by constructing relations among text units and across text units and information stored in the memory (Peled & Wittrock, 1990, p. 75).

The model of generative learning implies that a learner must be active in the generation of relationships, activly involved in the instruction, attentive to informationional structures, and aware of those mediational processes being used (Wittrock, 1985).

The fundamental principle of the generative model of learning is "that people tend to generate perceptions and meanings that are consistent with their prior learning" (Wittrock, 1974a, p. 88). Wittrock (1974a) contrasts the generative learning model with the concepts of meaningfulness or semantic processing models by explaining that the generative model predicts "that learning is a function of the abstract and distinctive, concrete associations which the learner generates between his understanding, which is defined by long-term memory, and the stimuli" (p. 89).

Wittrock (1974b) stresses that instructional designers should look beyond the instruction as nominal stimuli and see it as what it becomes to the learner based on the learner's individual context. The focus is not on what the instruction does but rather on what it causes the learner to do (Wittrock, 1974b).

Generative Learning as a Sub-set of Mathemagenic Behaviors

Peper and Mayer (1978) refer to the existence of mathemagenic and generative learning as contrasting. How can a mediational activity be both? Rothkopf (1970) refers to mathemagenic behavior as any behavior which induces learning. Generative learning also refers to behaviors which induce learning. But since generative learning requires the construction of new meaning from the assimilation of informational units it becomes a distinctive subset of mathemagenic behaviors.

Grabowski (in progress) provides an explanation as to how generative learning relates to mathemagenic effects. She explains that since generative learning refers specifically to mental activities, or conscious, covert mental processing, it is much more defined than mathemagenic effects which refer to all covert and overt, conscious and unconscious mental processing. She states the logical premise that since mathemagenic processing includes covert, conscious processing generative learning is a mathemagenic processing subset. "All generative learning produces a mathemagenic effect, but not all mathemagenic activities can be classified as generative" (Grabowski, in progress, p. 10).

So is note taking a mathemagenic activity or a mathemagenic/ generative activity? It depends on the nature of the activity. A note taking activity which involves elaboration of the presented information will require that the learner access prior knowledge and process the old and new information together thus generating a new and idiosyncratic meaning beyond the presented information. If, however, information is novel to the learner Peper and Mayer (1978) state:

> A tentative hypothesis is that when the material is unfamiliar and subjects have not developed efficient encoding strategies, mathemagenic activities aimed at encouraging assimilative rather than additive encoding are likely to be most successful (p. 521).

Peper and Mayer (1978) raise the interesting question of which approach is better: an instructor provided or learner generated approach to designing instructional materials. Discussed previously was the controversy over whether instructional designers could impose a specific processing strategy on learners through the manipulation of instructional materials and activities.

Rickards and August (1975) in their study of generative underlining found that subjects retained more information from prose which they underlined (learner generated) than from prose underlined by the experimenter (instructor provided) or not underlined at all. Rickards and August (1975) maintain that when a learner is permitted to underline any text which they deem important they exercise the freedom to select those passages which best "fit" their idiosyncratic cognitive structures and are better able to assimilate the new information with already existing information.

Rickards and August (1975) also observe that incidental learning is increased by a generative strategy. The assumption is therefore made that learning is a constructive activity and that those instructional activities which are generative in nature will best foster learning (Rickards and August, 1975).

Imagery Research In Mathemagenic Behavior

Embedded questions, as mentioned before, are most often used to induce mathemagenic behavior. Re-

search focusing on imagery, however, has greatly illuminated the relationship of mathemagenic/instructor provided and mathemagenic/generative inducing activities.

Instructionally Induced Imagery

Anderson and Kulhavy (1972) investigated the effect imagery instructions had on learning from prose passages like those found in text books. They found that providing learners with instructions to use imagery does not mean that they will necessarily do it. One third of their imaging subjects reported using imagery only at the beginning of the study or not using imagery throughout. Additionally, more than half of their control group, who received no instruction to image, reported using imagery during the study. Their conclusion was that providing instruction to image while reading text does not assure that learners will employ that strategy. Nor does not providing instruction assure that learners will not utilize the strategy. These findings agree with Thornton et al. (1990) who found that learners will often rely on previously adopted strategies.

An alternative to Anderson and Kulhavy's (1972) approach would be to provide encouragement to utilize a specified strategy. Lesgold et. al. (1975) attempted to induce mental imagery through the use of learner generated imagery and prompting. Subjects were instructed to generate stick figure illustrations after reading a passage of text. They were to use these illustrations as prompts for remembering details from the passage of text. Throughout the instruction subjects were encouraged to illustrate every picturable fact from the text. The subjects (third and fourth grade students) were permitted to examine the text while generating the illustrations. The experimenters believed, however, that such a review would become less frequent as subjects learned to gather facts for illustrating while reading.

It is important to note that, although the imagery instruction was shown to significantly improve recall of information, subjects neglected to utilize the strategy unless they were reminded to do so (Lesgold et al., 1975). This study seems to reinforce the theory that a mathemagenic/generative form of imagery instruction facilitates the recall of prose information. This study, however, stipulates that content was highly imagible. Complex or unfamiliar images were not studied.

A further improvement upon Anderson and Kulhavy's (1972) approach was that utilized by Carnine and Kinder (1985). They incorporated an overt activity, verbalizing generated visual imagery, to help induce the use of imagery in their subjects. Although the use of corrective feedback cannot be ignored, Carnine and Kinder (1985) maintain that the addition of an overt activity may direct learners to utilize imagery as a mediational processing technique.

Carnine and Kinder (1985), Lesgold et al. (1975), and Anderson and Kulhavy (1972) demonstrate that the use of imagery as a mediational processing technique facilitates the learning of information from prose. They further demonstrate that the utilization of an overt activity can induce a learner to utilize a specified strategy; in this case imagery. Underlying both of these considerations is the notion of utilizing a generative approach to structuring instructional events; a notion which all of these studies support.

Bull and Wittrock's (1973) study compared fifth-grade students ability to remember the definitions of nouns across three treatments. The first treatment involved "self-discovered" images. The second treatment involved experimenter provided images, and the third treatment was provided with verbal definitions alone. They hypothesized that the two imagery groups

would remember more definitions than the verbal definitions alone group and that the self-discovered images group would perform better than the experimenter provided images group. It is logical that Bull and Wittrock (1973) would assume that the imagery groups would facilitate storage of definitions better than non-imagery groups (Taylor, Josberger, & Prentice, 1970; Anderson & Kulhavy, 1972).

The results of Bull and Wittrock's (1973) study indicate that the self-discovery images group performed better on recalling definitions than did the experimenter provided images group. Both groups did, in fact, perform significantly better than did the verbal definitions alone group. Subjects were not tested on their ability to image. Whether they actually utilized an imagery strategy is unknown.

Further research exists which supports the hypothesis that mental imagery facilitates reading comprehension (Gambrell & Bales, 1986; Gambrell, 1981; Giesen & Peeck, 1984; Peters & Levin, 1986; Pressley, 1976, 1977a; Sadoski, 1983, 1984, 1985; Steingart & Glock, 1979). The idea of self-discovered imagery producing stronger effects than experimenter provided images is in line with generative learning theory (Wittrock, 1967), since self-discovered images are more idiosyncratic they will act as a higher associative mediator (Bull & Wittrock, 1973).

The notion of imposing an imagery strategy on the learner reopens the controversy of instructionally manipulated processing strategies. Recall that Thornton et al. (1990) state that imposed processing strategies may interfere with processing strategies which the learner is already familiar with and prefers. This would seem to contradict the above findings that the imaging strategy was imposed with successful results. But it should be remembered that research has shown that by the age of 6 or 7 years, children are capable of producing internal visual imagery and that by the age of 8 years children can successfully apply the strategy of self-generated imagery to complex tasks such as prose learning (Lesgold, et al., 1975; Pressley, 1976).

It would seem logical to infer that imagery is a strategy which learners develop and utilize at a relatively early age. Attempts to induce learners to utilize such a strategy are therefore not imposing a novel method upon the learner but are rather encouraging the learner to utilize a strategy already in their repertoire.

There is a particular issue which the literature indicates researchers, interested in imagery, have yet to fully explore. That concern is the idea of idiosyncratic images acting as higher associative mediators. While this may well be true for the learning of definitions and familiar concepts it is a questionable technique when the object is to learn an accurate spatial understanding of a complex and/or unfamiliar concept. A learner could be said to possess spatial understanding of an object when he/she can accurately identify or illustrate a simple representation of the object.

For instance, if average American learners were required to generate a mental image of a "fire truck" they would probably be able to do so. There would also be little doubt that while each individual's image would possess some common qualities (wheels for instance) they would also be quite idiosyncratic. In this case the theory that a generative approach of imagery production would better facilitate the retention of the word "fire truck" would probably be validated.

But what if the learner were asked to generate a visual image of an unfamiliar concept such as a "plant cell." If learners are unfamiliar with what plant cells look like the best they may be able to do is generate a paired-associate such as generating a visual image of a tree in a jail cell (the stimulus) with the term plant cell (the response). While the visual image may aid the learner in retrieving the information concerning a plant cell it will not aid their spatial understanding of what a plant cell looks like.

If the instructional objective is to develop or identify a spatial representation of a novel object, then the paired-associate method will fail to help the learner develop such an understanding. Remember that Peper and Mayer (1978) stated tentatively that if material is unfamiliar to subjects a mathemagenic/instructor provided approach may be more successful than a mathemagenic/generative one.

This falls in line with Anderson and Armbruster's (1990) concept of modeling. By providing the learner with an example of what a plant cell looks like the learner can then match the provided image with the associated term and information. Although no generation of an idiosyncratic meaning is fostered, the instructional objective of developing a spatial understanding would be met.

A fundamental question, which must be asked, is whether or not the learner is utilizing visual imagery as a mediational force during either the mathemagenic/instructor provided strategy or the mathemagenic/ generative strategy. By imposing an instructional activity which requires the learner to utilize a visual strategy (copying, tracing, drawing, etc.) the instructor should be able to determine whether the learner utilized the desired mediational force under the premise that the successful completion of such an activity would both induce and encourage the use of visual imagery. In other words, learners would be unable to successfully complete an evaluative measure involving identification or drawing unless they possessed an accurate visual image of the object in question. This notion is supported by Linden and Wittrock (1985, p 55) who state "The measures of learner generations clearly indicate, independently of the retention, comprehension, or other dependent measures obtained later on separate tests, the existence of the functional treatments" (Linden & Wittrock, 1981, p55).

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